Italian Journal of Animal Science 2014; volume 13:3174

PAPER

Wool quality traits of purebred and crossbred Merino lambs orally drenched with *Spirulina* (*Arthrospira platensis*)

Benjamin W.B. Holman,[1] Arash Kashani,[1] Aduli E.O. Malau-Aduli[1,2]

[1]Tasmanian Institute of Agriculture, University of Tasmania, Hobart, Australia
[2]Faculty of Health, Medicine and Molecular Sciences, James Cook University, Townsville, Queensland, Australia

Abstract

The objective of this study was to evaluate the effect of *Spirulina* supplementation, sire breed and sex on the wool characteristics of purebred and crossbred Merino weaned lambs under a single pasture-based management system. Lambs sired by Merino, White Suffolk, Dorset, Black Suffolk breeds were randomly allocated into 3 treatments – the control group grazing without *Spirulina* (0 mL), low (100 mL) and high (200 mL) *Spirulina* groups. All lambs were kept as a single mob in paddocks, grazed for 9 weeks and wool samples analysed. Differences in wool quality between the control and supplemented groups were not significant (P>0.05). However, sire breed significantly (P<0.001) influenced fibre diameter, spinning fineness, comfort factor and fibre curvature with purebred Merinos having superior wool quality than crossbreds. Wethers grew higher quality wool than ewes. *Spirulina* has a potential as an alternative supplementary bioresource in dual-purpose sheep feeding because it does not compromise wool quality in supplemented weaner lambs.

Introduction

Spirulina (*Arthrospira platensis*) is an edible microalga with potential as an alternative protein-rich lamb supplement due to its high protein content (60-70%; Becker, 2007). *Spirulina* is also rich in essential vitamins, minerals, fatty acids, amino acids and carotenoids (Table 1). Supplementary feeding with *Spirulina* has been previously tried with several animal species (Holman and Malau-Aduli, 2013), but to the best of our knowledge, there is presently no published information on the impact of *Spirulina* supplementation on wool quality traits in dual purpose lambs.

Across Australia, farmers have adopted dual purpose sheep systems with both wool and meat production goals (Rowe, 2010). This objective is generally achieved by mating meat-type rams to a core flock of purebred Merino ewes and exploiting heterosis to optimise lamb growth. Current lamb meat prices are high (Martin and Phillips, 2011), while wool prices are at a historical low (Gibbon and Nolan, 2011). Hence, profitability in dual purpose sheep systems is now mostly driven by lamb growth and early attainment of slaughter weight.

Lamb growth is commonly enhanced through protein-rich supplementation using canola meal, lupins, barley and wheat. Varying and inconsistent reports on the impact of these supplements on wool quality have been reported (Malau-Aduli and Akuoch, 2012; Masters and Mata, 1996). Any decline in wool quality due to supplementary feeding can affect total farm profitability. Therefore, we tested the hypothesis that the oral drenching of grazing purebred Merino and crossbred lambs with Spirulina supplement would not elicit a significant variation and decline in wool quality. The experimental objective was to evaluate the effect of *Spirulina* supplementation and interactions with sire breed and sex on wool quality traits in purebred and crossbred Merino lambs under a single pasture-based management.

Corresponding author: Dr. Aduli E.O. Malau-Aduli, School of Land and Food, Tasmanian Institute of Agriculture, University of Tasmania, Private Bag 54, Hobart 7001, Australia.
Tel. +61.3.6226.2717 - Fax: +61.3.6226.2744.
E-mail: aduli.malauAduli@utas.edu.au; aduli.malauaduli@jcu.edu.au

Key words: *Spirulina*, Wool quality, Merino crossbred, Supplementation, Dual purpose.

Acknowledgments: this research was funded by grants and scholarships from the Australian Wool Education Trust (AWET) and The University of Tasmania (UTAS). We appreciate the valuable inputs of Chris Gunn and Barrie Wells during the sheep breeding and feeding trials.

Received for publication: 4 November 2013.
Accepted for publication: 17 March 2014.

Italian Journal of Animal Science 2014; 13:3174
doi:10.4081/ijas.2014.3174

Materials and methods

This study was conducted at the University of Tasmania Farm, Cambridge, Tasmania, Australia. All procedures had the University of Tasmania Animal Ethics approval and were conducted in accordance with the 1993 Tasmania Animal Welfare Act and the 2004 Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.

Animal management and experimental design

A completely randomised experimental design in which 24 weaner lambs with an average live weight of 37.6±5.2 kg and body condition score of 3.1±0.4 at 6 months of age was utilised. The experimental lambs had an inbuilt factorial of 4 sire breeds (Merino, White Suffolk, Dorset, Black Suffolk) and 2 genders (ewes, wethers). Lambs were randomly allocated into 3 treatments (8 lambs per treatment) – the control group grazing and *ad libitum* drinking water only without (0 mL), or low (100 mL of Spirulina) or high (200 mL) content of *Spirulina* dissolved in water. The *Spirulina* was commercially purchased (TAAU, Darwin, Australia) as a powder and dissolved in water utilising a weight:volume ratio of 1 g:10 mL (low) and 2 g:10 mL (high) and the solution delivered to the lambs by oral drenching. Both control and *Spirulina* supplemented groups of lambs were kept in a single mob and had *ad libitum* access to the basal diet of ryegrass pastures and crushed barley whose nutrient composition is depicted in Table 2. Lambs in the low and high *Spirulina* treatment groups were individually drenched daily with *Spirulina* solution prior to being released with the control group of lambs (also drenched with water only) into paddocks sown with ryegrass pastures. The lambs were allowed 3 weeks of adjustment to the *Spirulina* drench prior to the experimental phase lasting 6 weeks. At all times, lambs had *ad libitum* access to clean drinking water.

Wool sampling and analysis

Midside wool samples of approximately 10 cm^2 were shorn from each lamb by an experienced shearer using Oster-Sunbeam electric shears (Boca Raton, FL, USA; Baxter and Cottle, 1998) at the start and completion of the feeding trial. Samples were accurately catalogued and commercially analysed at the Australian Wool Testing Authority (Melbourne, Australia) using LaserScan equipment (Heath *et al.*, 2006). The wool quality traits assessed were: mean fibre diameter (FD) using LaserScan OFDA, standard deviation (SD), coefficient of variation (CV), comfort factor (CF), spinning fineness (SF), fibre curvature (CURV) and clean fleece yield (YIELD).

Chemical analysis of the basal diet

Dry matter content of the basal diet was determined by drying samples to a constant weight at 65°C in a fan forced oven. Ash content was determined by combusting samples in a furnace at 550°C for 5 h. Neutral and acid detergent fibre contents were measured using an Ankom fibre analyser (ANKOM 220; Ankom Technology, Macedon, NY, USA) (van Soest *et al.*, 1991). Total nitrogen (N) content was measured using the Kjeldahl method (van Soest *et al*., 1991) and the crude protein estimated by multiplying N by 6.25. Ether extract was determined by the Soxhlet methodology, while *in vitro* digestibility and metabolisable energy were estimated using near infrared reflectance spectroscopy (Garnsworthy and Unal, 2004).

Statistical analysis

All data were analysed using the 'Statistical Analysis System' software package (SAS, 2009). Initially, summary statistics by *Spirulina* supplementation level, sire breed and sex, were computed with means, standard deviations, and minimum and maximum values scrutinised for any data entry errors or outliers. Subsequently, multivariate analysis of variance in generalised linear model (PROC GLM) and mixed model (PROC MIXED) analyses (SAS, 2009) were used to fit the fixed effects of *Spirulina* supplementation level, sire breed, sex and their second-order interactions on wool FD, CV, SD, SF, CF, CURV, and YIELD. Sire was fitted as a random effect in the Mixed Model. Significant differences and mean separations were carried out using Duncan's multiple range and Bonferroni's probability pairwise comparison tests (SAS, 2009) Pearson correlation coefficients between dependent variables were estimated using PROC CORR (SAS, 2009) with significance determined using Bonferroni's probability pairwise comparison test (SAS, 2009).

Results

Effect of *Spirulina* supplementation level, sire breed and sex on wool traits

Spirulina supplementation level had no significant effect on any wool quality trait, compared to the control group ($P>0.05$; Table 3). However, wethers produced wool with lower FD ($P<0.046$), SD ($P<0.046$) and SF ($P<0.019$) than ewes. Comfort factor was lower in ewes than wethers (79.9±3.31 and 88.1±2.2%, respectively; Table 4).

Merino-sired lambs had lower FD (18.0±0.1 μm), SF (17.1±1.0 μm), CURV (63.5±1.5°/mm) and higher CF (96.2±3.5%) compared to all other sire breeds studied ($P<0.001$). Among the crossbreds, Black Suffolk-sired lambs had the highest SF (26.1±0.6 μm) and Dorset-sired lambs the least (23.8±0.9 μm; Table 4).

Effect of interactions between *Spirulina* supplementation level and sex on wool traits

It was evident from Figure 1 that ewes receiving high *Spirulina* supplementation levels had higher wool YIELD than their wether counterparts (77.2±0.8 and 71.9±1.4% respec-

Table 1. Nutrient composition of *Spirulina* (*Arthrospira platensis*).

Components	Value
Vitamins and minerals	
beta-carotene, μg/100 g	140,000
Total carotenoids, mg/kg	1700
Provitamin A, U kg^{-1}	2,330,000
B_3, mg/kg	130-150
B_{12}, mg/kg	1.5-2.0
Calcium, mg/kg	1200
Magnesium, mg/kg	3300
Sodium, mg/kg	22000
Potassium, mg/kg	26000
Fatty acids, % total	
Gamma-linolenic acid	17.1-40.1
Amino acids, % total protein	
Methionine	2.05-2.50
Cysteine	0.5-0.9

Table 2. Chemical composition of feed components.

Chemical composition	Feed components		
	Spirulina	Barley grain	Ryegrass pasture
DM, g/100 g	96.0	93.2	44.7
NDF, g/100 g DM	32.6	18.5	22.4
NDFn, g/100 g DM	30.3	17.2	20.8
ADF, g/100 g DM	18.3	6.0	23.0
NFC, g/100 g DM	7.9	68.7	43.5
Ash, g/100 g DM	9.5	3.2	11.9
EE, g/100 g DM	5.9	2.0	3.0
CP, g/100 g DM	62.2	8.9	20.8
ME, kJ/100 g DM	1707.5	1723.7	1701.1

DM, dry matter; NDF, neutral detergent fibre; NDFn, nitrogen free NDF; ADF, acid detergent fibre; NFC, non fibrous carbohydrate; EE, ether extract; CP, crude protein; ME, metabolisable energy.

Table 3. Least square means and standard error of *Spirulin*a supplemented crossbred and purebred Merino lambs' wool quality traits.

Wool quality trait	*Spirulina* supplementation level			P
	Control	Low	High	
FD, μm	23.7±1.1	24.6±1.3	24.3±1.2	0.687
SD	4.6±0.3	4.4±0.2	16.8±1.2	0.542
CV, %	19.5±0.8	17.8±0.5	5.1±0.8	0.123
CF, %	85.5±3.0	81.8±4.3	84.7±3.5	0.620
SF, μm	22.9±1.0	23.4±1.2	23.0±1.1	0.865
CURV, °/mm	71.4±2.8	71.4±2.3	73.8±2.3	0.657
YIELD, %	75.0±1.4	72.7±1.0	74.6±1.0	0.173

FD, mean fibre diameter; SD, standard deviation; CV, coefficient of variation; CF, comfort factor; SF, spinning fineness; CURV, fibre curvature; YIELD, clean fleece yield.

tively). All other interactions between *Spirulina* supplementation level and sex were not significant (P>0.05).

Effect of sire breed and sex interactions on wool traits

Black Suffolk-sired ewe lambs had lower CURV than their wether counterparts, 67.8±2.0 and 80.8±3.0°/mm, respectively (P<0.032), as depicted in Figure 2. No other second-order interactions between sire breed and sex reached statistical significance (P>0.05).

Correlations among wool traits

Table 5 shows that there were highly significant relationships (P<0.001) between FD and SF (0.99), CF with both FD (-0.87) and SF (-0.88), FD and CURV (0.39), SF and CURV (0.37), and SD with YIELD (0.29). All other correlations were not significant (P>0.05).

Discussion

Wool growth and quality depend on the type of protein supplement, its nutritional value, and level of supplementation (Malau-Aduli *et al.*, 2009b; Masters *et al.*, 1998; Rowe *et al.*, 1989). Protein-rich supplements vary in amino acid availability thus affecting follicular uptake and wool fibre proliferation (Li *et al.*, 2008). Therefore, increasing amino acid availability within the body-pool by increasing protein-rich supplementation generally results in heightened follicular uptake that favours nutrient partitioning towards faster growth, but also coarser wool fibre synthesis in crossbred lambs (Malau-Aduli and Holman, 2010; Malau-Aduli *et al.*, 2009a). This coarser fibre is characteristic of lesser quality wool (Holman and Malau-Aduli, 2012). However, in this study, there were no observable detrimental effects of *Spirulina* supplementation on wool quality traits. *Spirulina* has a lower content of sulphur-containing amino acids compared to other protein-rich lamb supplements (Ciferri and Tiboni, 1985; Volkmann *et al.*, 2008). Methionine and cysteine are sulphur amino acids which are essential for wool proliferation (Liu and Masters, 2003). Cysteine plays a vital

Table 4. Sire breed and sex least square means and standard error of *Spirulina* supplemented crossbred and purebred Merino lambs' wool quality traits.

	Wool quality trait						
	FD, μm	CV, %	SD	CF, %	SF, μm	CURV, °/mm	YIELD, %
Sire breed							
Black Suffolk	27.2±0.7^{a}	19.4±0.9	5.3±0.2	74.5±4.3^{c}	26.1±0.6^{a}	74.3±3.0^{a}	74.2±1.3
Dorset	25.0±0.9^{a}	18.1±0.7	4.6±0.3	85.4±3.8^{b}	23.8±0.9^{b}	75.2±2.7^{a}	74.1±1.2
Merino	18.0±1.1^{b}	17.0±1.4	4.4±1.1	96.2±3.5^{a}	17.1±1.0^{c}	63.5±1.5^{b}	75.2±1.7
White Suffolk	26.7±0.4^{a}	17.7±1.1	4.7±0.2	79.9±2.1^{bc}	25.3±0.3^{ab}	75.9±2.5^{a}	72.7±1.0
P	0.001	0.474	0.703	0.001	0.001	0.004	0.399
Sex							
Ewes	25.1±0.9^{a}	18.3±1.0	5.3±0.5^{a}	79.9±3.3^{b}	24.0±0.9^{a}	71.8±1.8	74.8±0.8
Wethers	23.4±0.9^{b}	17.8±0.4	4.1±0.2^{b}	88.1±2.2^{a}	22.2±0.9^{b}	72.7±2.2	73.4±1.0
P	0.046	0.620	0.046	0.016	0.019	0.721	0.186

FD, mean fibre diameter; CV, coefficient of variation; SD, standard deviation; CF, comfort factor; SF, spinning fineness; CURV, fibre curvature; YIELD, clean fleece yield. $^{a-c}$Column means within a fixed effect with different superscripts are significantly different (P<0.05).

Table 5. Pearson's correlation among wool quality traits.

	CV	SD	CF	SF	CURV	YIELD
FD	0.12 (ns)	0.17 (ns)	-0.87***	0.99***	0.39**	0.13 (ns)
CV		-0.27 (ns)	-0.18 (ns)	0.12 (ns)	0.37 (ns)	0.06 (ns)
SD			-0.25 (ns)	0.21 (ns)	-0.07 (ns)	0.29*
CF				-0.88***	-0.87 (ns)	0.04 (ns)
SF					0.35*	0.11 (ns)
CURV						0.21 (ns)

CV, coefficient of variation; SD, standard deviation; CF, comfort factor; SF, spinning fineness; CURV, fibre curvature; YIELD, clean fleece yield; FD, mean fibre diameter. ns, not significant (P>0.05); *P<0.05; **P<0.01; ***P<0.001.

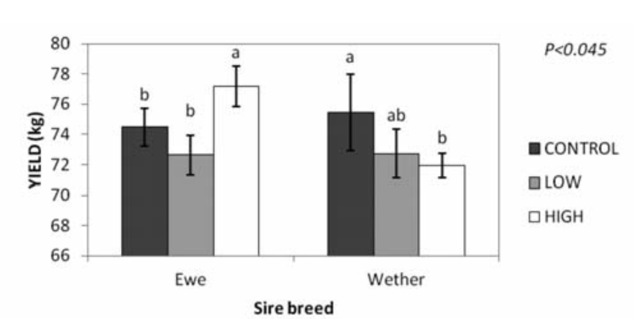

Figure 1. Interaction between *Spirulina* supplementation level and sex on clean fleece yield (YIELD) of grazing purebred and crossbred Merino lambs. Means (±standard error) within sire breeds with different superscripts are significantly different (P<0.05).

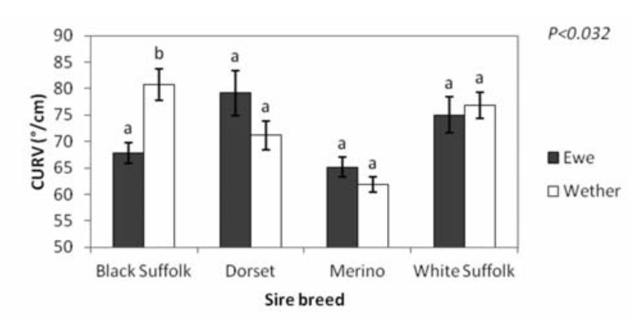

Figure 2. Interaction between sire breed and sex on fibre curvature (CURV). Means (±standard error) within sire breeds with different superscripts are significantly different (P<0.05).

role during the differentiation of intermediate filament- and keratin associated proteins during wool synthesis (Plowman, 2007). Furthermore, methionine acts as a source of cysteine in the transulphuration pathway (Liu and Masters, 2003). *Spirulina*'s relatively minor content of these sulphur amino acids could likely explain insignificant differences in wool traits between the unsupplemented control and *Spirulina* supplemented group of lambs.

Ewes generally have smaller live weights than wethers (Cam *et al.*, 2010; Holman *et al.*, 2012). This difference could result in considerable variation with other prioritised sinks requiring more of the available amino acids (Rogers and Schlink, 2010). Our sex and sire breed findings were similar to published literature that have demonstrated hormonal differences between sexes (Egan and Russell, 1981; Wallace, 1979) and wool follicle trait variations between sire breeds (Lee and Williams, 1993; Scales *et al.*, 2000) as having major impacts on wool traits. Similarly, the correlations between wool traits is in line with published literature (Notter *et al.*, 2007). The strongly positive correlation between FD and SF is expected as SF is calculated from FD and CV values (Butler and Dolling, 1992; Holman and Malau-Aduli, 2012). Likewise, CF represents the proportion of fibres over 30 μm (Holman and Malau-Aduli, 2012; Wood, 2003) and is a function of FD, thus the strong correlation between CF and FD. However, SF and CF had an antagonistic relationship, hence the negative correlation. The insignificant correlation between CF and YIELD with other wool traits has already been previously reported (Hatcher *et al.*, 2010).

Conclusions

The hypothesis that *Spirulina* supplementation via oral drenching will not be detrimental to wool quality in grazing purebred and crossbred Merino lambs holds true and should be accepted. The responses of lambs of different sire breeds and sex to *Spirulina* supplementation in terms of interaction effects on wool traits add to our current knowledge of supplementing crossbred sheep. Finally, there is the need for further investigation into the underlying mechanisms behind our findings, particularly with regard to circulating plasma metabolites and proteomic profiles of supplemented lambs. This would provide a comprehensive understanding of *Spirulina*'s future applications as a protein-rich lamb feed supplement.

References

Baxter, B.P., Cottle, D.J., 1998. The use of midside fleece fibre diameter distribution measurements in sheep selection. Wool Tech. Sheep Bree. 46:154-171.

Becker, E.W., 2007. Micro-algae as a source of protein. Biotechnol. Adv. 25:207-210.

Butler, K., Dolling, M., 1992. Calculation of the heritability of spinning fineness from phenotypic and genetic parameters of the mean and CV of fibre diameter. Aust. J. Agr. Res. 43:1441-1446.

Cam, M.A., Olfaz, M., Soydan, E., 2010. Body measurements reflect body weights and carcass yields in Karayaka sheep. Asian J. Anim. Vet. Adv. 5:120-127.

Ciferri, O., Tiboni, O., 1985. The biochemical and industrial potential of Spirulina. Annu. Rev. Microbiol. 39:503-526.

Egan, J., Russell, D., 1981. Growth and wool production of wethers and induced cryptorchids in a Poll Merino flock. Aust. J. Exp. Agr. 21:268-271.

Garnsworthy, P.C., Unal, Y., 2004. Estimation of dry-matter intake and digestibility in group-fed dairy cows using near infrared reflectance spectroscopy. Anim. Sci. 79:327-334.

Gibbon, C., Nolan, E., 2011. The Australian wool industry: a hedonic pricing analysis of the factors affecting price of Australian wool. pp 1-31 in Proc. 55th Conf. of the Australian Agricultural and Resource Economics Society, Melbourne, Australia. Available from: http://ageconsearch.umn.edu/bitstream/100552/2/Gibbon_AARES.pdf

Hatcher, S., Hynd, P.I., Thornberry, K.J., Gabb, S., 2010. Can we breed Merino sheep with softer, whiter, more photostable wool? Anim. Prod. Sci. 50:1089-1097.

Heath, W.A., Barkhuizen, J.W., Wright, O.E., 2006. The relationship between mean fibre diameter measurements by Airflow and Laserscan for South African wools. International Wool Textile Organisation ed., Brussels, Belgium.

Holman, B.W.B., Kashani, A., Malau-Aduli, A.E.O., 2012. Growth and body conformation responses of genetically divergent Australian sheep to Spirulina (Arthrospira platensis) supplementation. American J. Expt. Agric. 2: 160-173.

Holman, B.W.B., Malau-Aduli, A.E.O., 2013. Spirulina as a livestock supplement and animal feed. J. Anim. Physiol. An. N. 97:615-623.

Holman, B.W.B., Malau-Aduli, A.E.O., 2012. A review of sheep wool quality traits. Available from: http://eprints. utas.edu.au/12715/1/Holman_%26_Malau-Aduli_2012_ARRB_2(1)_pg_1-14_A_review_of_sheep_wool_quality_traits.pdf

Lee, G., Williams, A. 1993. Relationship of feed intake with cystine availability and wool growth in Merino wethers. Aust. J. Agr. Res. 44:973-991.

Li, L., Oddy, V.H., Nolan, J.V., 2008. Whole-body protein metabolism and energy expenditure in sheep selected for divergent wool production when fed above or below maintenance. Aust. J. Exp. Agr. 48:657-665.

Liu, S.M., Masters, D.G., 2003. Animo acids utilization for wool production. In: J.P.F. D'Mello (ed.) Amino acids in animal nutrition. CABI Publ., Willingford, Oxon, UK, pp 309-328.

Malau-Aduli, A.E.O., Akuoch, J.D.D., 2012. Sire genetics, protein supplementation and gender effects on wool comfort factor in Australian crossbred sheep. American J. Expt. Agric. 2: 31-46.

Malau-Aduli, A.E.O., Holman, B., 2010. Genetic-nutrition interactions influencing wool spinning fineness in Australian crossbred sheep. J. Anim. Sci. 88:469.

Malau-Aduli, A.E.O., Walker, R.E., Bignell, C.W., 2009a. Prediction of wool fibre diameter from protein and metabolisable energy digestibility cofficients in crossbred sheep. J. Anim. Sci. 86:498.

Malau-Aduli, A.E.O., Walker, R.E., Ranson, C.F., Sykes, J.M., Bignell, C.W., 2009b. Nutrition-genetics interaction in nutrient utilisation of canola and lupins by Australian sheep: prediction of wool fibre diameter. Page 50 in Proc. 7th Int. Workshop on Modeling Nutrition, Digestion and Utilisation in Farm Animals, Paris, France. Available from: http://eprints.utas.edu.au/9345/1/Malau-Aduli_et_al_2009_Paris_France.pdf

Martin, P., Phillips, P., 2011. Australian lamb: financial performance of slaughter lamb producing farms, 2008-09 to 2010-11. Commonwealth of Australia ed., Canberra, Australia.

Masters, D., Mata, G., 1996. Responses to feeding canola meal or lupin seed to pregnant, lactating, and dry ewes. Aust. J. Agr. Res. 47:1291-1303.

Masters, D.G., Peterson, A.D., Mata, G., Liu, S.M., 1998. Influence of liveweight, liveweight change, and diet on wool growth, staple strength, and fibre diameter in young sheep. Aust. J. Agr. Res. 49:269-278.

Notter, D.R., Kuehn, L.A., Kott, R.W., 2007.

Genetic analysis of fibre characteristics in adult Targhee ewes and their relationship to breeding value estimates derived from yearling fleeces. Small Ruminant Res. 67:164-172.

Plowman, J.E., 2007. The proteomics of keratin proteins. J. Chromatogr. B 849:181-189.

Rogers, G.E., Schlink, A.C., 2010. Wool growth and production. In: D.J. Cottle (ed.) International sheep and wool handbook. Nottingham University Press, Nottingham, UK, pp 373-394.

Rowe, J., Brown, G., Ralph, I., Ferguson, J., Wallace, J., 1989. Supplementary feeding of young Merino sheep, grazing wheat stubble, with different amounts of lupin, oat or barley grain. Aust. J. Exp. Agr. 29:29-35.

Rowe, J.B., 2010. The Australian sheep industry: undergoing transformation. Anim. Prod. Sci. 50:991-997.

SAS, 2009. Statistical analysis system, version 9.2. SAS Inst. Inc., Cary, NC, USA.

Scales, G.H., Bray, A.R., Baird, D.B., O'Connell, D., Knight, T.L., 2000. Effect of sire breed on growth, carcass, and wool characteristics of lambs born to Merino ewes in New Zealand. New Zeal. J. Agr. 43:93-100.

van Soest, P.J., Roberts, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Volkmann, H., Imianovsky, U., Oliveira, J.L., Sant'Anna, E.S., 2008. Cultivation of Arthrospira (Spirulina) platensis in desalinator wastewater and salinated synthetic medium: protein content and amino-acid profile. Braz. J. Microbiol. 39:98-101.

Wallace, A.L.C., 1979. The effect of hormones on wool growth. pp 115-126 in Proc. Nat. Workshop Physiological and environmental limitations to wool growth, Leura, Australia.

Wood, E., 2003. Textile properties of wool and other fibres. Wool Tech. Sheep Bree. 51:272-290.